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SCIENCE ABSTRACTS.

Section A.—PHYSICS.

DECEMBER 1916.

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SCIENCE ABSTRACTS.

Section A.—PHYSICS.

DECEMBER 1916.

GENERAL PHYSICS.

1313. *Wollaston Wire.* **C. Benedicks.** (Phys. Zeits. 17. pp. 319–322, July 15, 1916.)—Describes in detail a method of obtaining the finest Wollaston wire. After drawing out the wire as fine as possible, it is attached to a fine Pt-wire and heated for a short time to about 200°–400° C. The wire is then immersed in hot concentrated nitric acid for an instant to dissolve the silver coating. With this method wires of about 0·5 μ can be obtained. A. W.

1314. *Comparison of Aneroid and Mercury Barometers.* **W. G. Duffield.** (Engineering, 102. p. 347, Oct. 13, 1916. Paper read before the British Assoc.)—Describes a comparison between readings of a standard marine mercury barometer and a compound aneroid barometer on voyages to and from Australia, in order to obtain values of gravity over the ocean. For $g = p/h\rho$, where g is gravity, p is pressure as determined by the aneroid, h is the height of the mercury barometer, and ρ is the density of the mercury. The results, which are offered with reserve, suggest a decrease of gravity over the deep Indian Ocean, contrary to the theory of isostasy. R. C.

1315. *On Einstein's Equivalent Hypothesis and Gravitational Theory.* **F. Kottler.** (Ann. d. Physik, 50. 8. pp. 955–972, Sept. 5, 1916.)—In previous work [see Abs. 1484 (1914) and 397 (1915)] the question of relative acceleration or the possibility of the concealment of an accelerated motion has been discussed by the author. As this possibility lies at the basis of Einstein's equivalent hypothesis, the author now develops it in connection with gravitational theory. His paper is divided into the following nine sections : (1) Limits of the acceleration relativity based upon the author's previous work. (2) The Einstein equivalent hypothesis only admissible for the case of falling motion. (3) The Einstein result of falling motion derived from acceleration relativity (generalised Lorentz transformation). (4) Derivation of the homogeneous gravitational field from the equivalence. Gravity as an inertia phenomenon. (5) Arguments for the retention of the equivalence hypothesis. (6) The field equation for the homogeneous field on the basis of the equiva-

lence hypothesis. (7) Two hypotheses for the extension of the general case: (*a*) Isotropy of the field. (*b*) Euclidean nature of space. (8) The field of the mass point on the basis of the equivalence hypothesis. The differential equation of the field. The homogeneous field as a special case. Intimations as to still more general cases. (9) Comparison with the recent Einstein theory. H. H. Ho.

1316. *The Field of a Single Centre in Einstein's Theory of Gravitation, and the Motion of a Particle in that Field.* **J. Droste.** (K. Akad. Amsterdam, Proc. 19. pp. 197–215, 1916.)—In two previous communications [see Abs. 285 (1916)] the author has described a method for the calculation of the field of one as well as of two centres at rest, with such a degree of approximation as to account for all observable phenomena of motion in these fields. As a starting-point for this, Einstein's equations published in 1913 were taken. Einstein has now succeeded in forming equations which are covariant for all possible transformations, and by which the motion of the perihelion of Mercury is entirely explained. In consequence the author now makes the calculation of the field from the new equations, and commences by taking the field of a single centre at rest. This field is investigated completely and not, as before, confined to the terms of the first and second order only. Following this comes the investigation of the motion of a body so small that it does not produce any observable change in the original field. H. H. Ho.

1317. *On the Analysis of Oscillating Drops by means of Vortex Rings.* **V. Kutter.** (Phys. Zeits. 17. pp. 424–429, Sept. 15, 1916.)—The paper is divided into three sections. The first examines the production of vortices by means of falling drops. If liquid drops be allowed to fall, not too quickly, into another liquid from small heights varying from a few mm. to several cm., then vortex rings are produced which penetrate more or less deeply into the liquid according to the height fallen. The phenomenon is made more visible by the use of coloured fluids, *e.g.* a solution of potassium permanganate dropping into one of a ferrous salt; in this case the vortex ring only disappears when its reduction by the ferrous salt is accomplished. The author also shows how colourless drops may be observed to produce their rings. It might be opined that the rings penetrate deeper the greater the fall of the drops, but this is shown to be by no means the case, the depth of penetration being found to vary periodically with the increasing height of fall, *i.e.* the penetration depth is a periodic function of the time of fall. Section II deals with the determination of the surface tension by vortex rings, and the author shows how these offer a simple means for analysing the movements of oscillating drops. Experiments are described in which vortex rings of pure water were rendered visible by a very dilute hydrochloric acid solution of antimony trichloride, this causing the ring to assume a milky to white appearance according to concentration. Tables are given of the surface-tension results for the case of water. Good results were obtained for acids, alkalies, and salts, thereby demonstrating the utility of the method. A full description of the apparatus used is given. The method is of the highest value for the investigation of coloured solutions and may be extended indefinitely by the use of suitable indicators. Section III deals with the analysis of the oscillations, and Section IV with the interpretation of the vortex rings. Interesting experiments are described and the opinion expressed that here may be an experimental means of establishing the Helmholtz-Kelvin theory of vortex atoms. H. H. Ho.

1318. *Air-resistance to Spheres.* **R. Seeliger.** (Phys. Zeits. 17. pp. 419–423, Sept. 15, 1916.)—Deals with the air-resistance to balloons approximately spherical as experienced in their upward motion. The equation of motion is written $m \cdot d^2x/dt^2 = A - f(dx/dt, K)$, where A is the external force (buoyancy minus total weight), and f denotes a function of the velocity and of K, which latter is a quantity depending on the various geometrical and physical constants involved. This function is afterwards put as the product of three functions, namely: $\pi(p) \cdot \alpha(V) \cdot \psi(v)$. Of these, the first function $\pi(p)$ involves the physical constants viscosity, roughness of the surface, etc. The second function $\alpha(V)$ depends on the volume V of the balloon. The third $\psi(v)$ depends on the velocity v of the balloon. From certain observations it is inferred that $\alpha(V) = 2{\cdot}07V^{1/3} + V^{2/3}$ and $\psi(v) = 2{\cdot}24v + v^2$ for the cases in question. Other results are given in the form of graphs.

E. H. B.

1319. *The Local Circulation of the Atmosphere.* **W. H. Dines.** (Monthly Weather Rev. 44. pp. 182–186, April, 1916.)—Gives mean values of air temperature over England at different heights under cyclonic and anticyclonic conditions, showing that from 1 km. to 9 km., or up to the top of the troposphere, temperature is lower than the average over a cyclone and higher than the average over an anticyclone. Consequently the low pressure of a cyclone is not due to the warmth, and hence the lightness, of the overlying air. Pressure is low in spite of, and not because of, the temperature distribution. Another fundamental difference between cyclone and anticyclone is that the stratosphere is at a low altitude in the former and at a high one in the latter. Above 10 km. the temperature conditions are reversed—there the cyclone is warmer and the anticyclone colder than the average temperature for the height.

It is impossible to account for these results by the agency of radiation, for the temperature of the upper air is known sometimes to change more rapidly under pressure-changes than can be produced by the effect of radiation. But it is shown that the above properties of cyclone and anticyclone can be satisfactorily accounted for by the dynamical heating and cooling effects which are produced by changes of pressure in accordance with the adiabatic formula, $\delta T/T = 0{\cdot}29\ \delta P/P$, where T is temperature on the absolute scale and P is pressure. If it be allowed that changes of pressures at 9 km. are the cause of the phenomena, then the observed results mentioned above and others referred to in the paper are shown to follow as applications of this principle.

R. C.

1320. *Free Air Data, Fort Omaha (Nebraska), July,* 1914. **W. R. Blair.** (Monthly Weather Rev. 44. pp. 247–264, May, 1916.)—A series of registering balloon ascents was made covering the period July 1–22, 1914, while throughout the 27½ hours from 12.30 p.m. on July 17 to 4 p.m. on July 18 an ascent was made every 2½ hours. The latter series was with the special object of studying the diurnal variation of the different elements up to great heights. It is hoped to carry out further series of this kind on future occasions. The balloons were observed through two theodolites on a base of 5088 m., and the heights thus determined trigonometrically were compared with those obtained in the customary way from the recorded pressure and temperature. The individual results are tabulated and mean values taken which show a difference of about 1 % up to 17 km. height. Temperature-height diagrams are plotted for each ascent. The 2½-hourly series show the setting-in of a

temperature inversion near the surface with the night cooling of the ground. With the advent of solar heating in the morning the normal gradient re-establishes itself in the lower levels, but traces of the inversion are visible at about 1 km. height until the following afternoon. Curves showing the diurnal range of temperature at different heights exhibit the curious fact that the range at 10 km. height was greater than at ground-level. This may have been due to a considerable change of absolute humidity which was taking place during the period. From the theodolite observations it was found that taking the whole series of ascents, above the 5 or 6 km. level a steady westerly wind prevailed up to about 15 or 16 km., while above 20 km. an increasing easterly current was found. J. S. Di.

1321. *Optical Deterioration of the Atmosphere in July and August,* 1916. **J. Maurer.** (Nature, 98. p. 90, Oct. 5, 1916.)—From observations in the Swiss Alps of the sun's aureole and of twilight phenomena, it appears that a remarkable deterioration in the optical properties of the atmosphere occurred during the last ten days of July and in Aug., 1916. The observations obtained were of a similar character to those of 1883–4, 1902–3, and 1912, which were associated with the volcanic eruptions that occurred in those years. R. C.

1322. *The Pyranometer: an Instrument for Measuring Sky Radiation.* **C. G. Abbot** and **L. B. Aldrich.** (Smithsonian Misc. Coll. 66. 7. [9 pp.], May, 1916.)—The principle of the instrument is derived from that of the well-known Ångström *pyrheliometer*. Another type of instrument devised by K. Ångström has two blackened strips placed alternately with two polished gold-plated ones. This is useful for measuring the outward radiation to the sky, but cannot be used in the daytime to determine the radiation scattered from sunlight by the atmosphere, as the absorption coefficient of the bright strips for these rays is not even approximately zero, and thus the apparatus fails in principle. The instrument described in this paper is the outcome of an attempt to overcome this drawback. Instead of using two strips of different absorption coefficients, kept at the same temperature by an electric current passing through one of them, as in the Ångström type, the idea was developed of having two blackened strips of similar absorbing power, but with different powers of conducting away the heat absorbed. This effect is obtained by having the two strips of different thicknesses and soldering the ends of each to blocks of copper which carry away the heat. The action is as follows:—With no radiation falling upon them the two will be at the same temperature, but for every value of the incoming (or outgoing) radiation there will be a corresponding temperature-difference between them after the steady state has been reached. This difference can be measured by suitable thermo-couples in the rear connected to a galvanometer. The remaining part of the apparatus provides means for passing an electric current through the two strips in parallel, suitable resistances being introduced so that the heating produced in each strip is the same. In taking a reading the two strips are exposed to the radiation to be measured and the deflection of the galvanometer is noted. This indicates their difference of temperature. An electric current is now passed through the strips (providing equal heating in each, as in the case of the radiation), and is varied until the same galvanometer deflection as before is produced. This current is measured on an ammeter, and if the constant of the instrument is known it is easy to calculate what heat is being produced in each of the strips. This being the same as that received from the incoming radiation, the latter is thus determined.

The instrument may be used both for scattered radiation from the sky and also for direct solar radiation. A series of comparative readings between this instrument and a standard pyrheliometer showed satisfactory agreement between the two. A second type of pyranometer was devised in which only one strip was employed instead of two, and this also is described. J. S. Di.

1323. *Radiation received from the Sun and Sky at Madison, Wisconsin.* **H. H. Kimball** and **E. R. Miller.** (Monthly Weather Rev. 44. pp. 180–181, April, 1916.)—The max. daily amount of radiation received on a sq. cm. of horizontal surface at Madison varies from 220 cals. in Dec. to 770 cals. in June. The corresponding mean daily amounts are 130 and 530 cals. The quantities for June are very similar to the amounts obtained at Washington, but in winter the Washington values are higher, as might be expected from the difference in latitude of the two stations. R. C.

1324. *The Planetary System of Convection.* **W. R. Blair.** (Monthly Weather Rev. 44. pp. 186–196, April, 1916.)—Gives a revised account of the general circulation of the atmosphere based upon observations at the surface, at mountain stations and in the free upper air, supplemented by hypothetical data in the absence of actual observations. R. C.

1325. *Circumhorizontal Arc Observed.* **J. T. Gray.** (Monthly Weather Rev. 44. pp. 245–246, May, 1916.)—At about 1 p.m. on June 5, 1916, at Cincinnati, a vividly coloured arc was observed, parallel to the horizon, at an altitude of about 20°, with perhaps a slight upward curve at either extremity. The arc was 30° or more in extent and so situated that its middle point appeared vertically beneath the sun. The solar distance was 46½°. It seems reasonably certain that this was the "circumhorizontal arc" or "lower tangent arc of the 46° halo," which has very rarely been observed. The sky at the time was everywhere visibly covered with thin cirrus or cirro-stratus cloud. J. S. Di.

1326. *Disappearance of Snow in California.* **A. J. Henry.** (Monthly Weather Rev. 44. pp. 150–153, March, 1916.)—A snow covering disappears slowly under the conditions of a low temperature and little wind. The average loss by evaporation in these circumstances in California is about ¾ in. per day. High temperature, brisk wind, and much sunshine are the most unfavourable conditions for the conservation of a snow covering. The daily loss of snow may then vary from 3 or 4 in. in the case of old snow to 10 in. in the case of freshly fallen snow. R. C.

1327. *The Currents of Lake Michigan.* **C. McD. Townsend.** (West. Soc. Eng., J. 21. pp. 293–305; Disc., 305–309, April, 1916.)—Observations made at different points have led the author to conclude that the currents are directly caused by the winds blowing at the time. Some earlier measurements made in 1892–4 led the U.S. Weather Bureau to the conclusion that there was a permanent system of currents flowing southerly down the west side of the lake, then curving round at the southern extremity and flowing up again along the east shore. The recent series of experiments did not harmonise with this theory, and it is concluded that there are no permanent currents of the type suggested. In addition to the discussion of currents, data are also given about the water temperature at different depths and in different parts of the lake. J. S. Di.

1328. *On the Geyser of Onikôbé.* **K. Honda** and **T. Soné.** (Tôhoku Univ., Sci. Reports, 5. pp. 249–261, Aug., 1916.)—Gives an historical account of the Onikôbé Geyser on the eastern side of the central group of the mountain ranges of North Japan, and describes a self-recording air thermometer for investigating the temperature changes that occur in the underground channel through which the hot water is supplied. Eruptions occur on the average about once every hour, and are indicated on the records by sudden increases of temperature occurring at nearly regular intervals. An artificial increase of pressure produced by raising the level of the water in the basin surrounding the geyser increases the period of eruption, and changes of atmospheric pressures are observed to produce corresponding effects upon the period. After each eruption the water in the basin returns underground through the channel.

An explanation of these results is offered. It is based upon the variation of the boiling-point of water under varying pressures. R. C.

1329. *Variation of Solar Radiation.* **C. G. Abbot, F. E. Fowle,** and **L. B. Aldrich.** (Smithsonian Misc. Coll. 66. 5. [24 pp], May, 1916.)—A short account is given of the method of observation at the new station on Mt. Wilson, established in working order during 1913, and tables of the results show the mean distribution of intensity of radiation over the sun's disc, changes in radiation from year to year and also from day to day. Curves are given showing the variability during 1913–1914. The ratio of change of contrast between centre and limb and change of solar constant appears to differ from year to year, but further work on this will be continued. With regard to the short-period changes, it is suggested that the difference of brightness between centre and limb may be a consequence of decreased effective temperature of the radiating surface rather than the result of an absorbing atmosphere as was formerly thought. To explain these varying results, two causes of change are supposed to be operative. One, going with increased solar activity, is regarded to be increased effective solar temperature, producing increased radiation and increased contrast. The other, altering from day to day, may be the increased transparency of the solar envelopes, which produces increased radiation but decreased contrast. All these changes are greater for shorter wave-lengths. C. P. B.

1330. *Effect of Haze on Solar Rotation Measures.* **R. E. DeLury.** (Roy. Astron. Soc. Canada, J. 10. p. 345, 1916. Nature, 98. p. 99, Oct. 5, 1916. Abstract. Astrophys. J. 44. pp. 177–189, Oct., 1916.)—The effect of terrestrial atmospheric haze on spectrographic measurements is due to the superposition of a weakened solar spectrum over the main spectrum under examination. As this added spectrum would show no displacements, the measurements of the blended lines would indicate velocities systematically too low, and, moreover, would vary from line to line, according to the character of the line examined. C. P. B.

1331. *Anomalous Dispersion in the Sun.* **J. Evershed.** (Observatory, No. 505. pp. 432–434, Oct., 1916.)—From an investigation of solar and arc spectra Albrecht announced results in accordance with the requirements of the anomalous dispersion theory [Abs. 296 (1916)]. Direct comparisons of the spectra in the laboratory led Royds and Evershed to doubt the validity of Albrecht's conclusions [Abs. 1006 (1916)], and it is now shown that Albrecht's tables are affected with disabilities well known to workers with comparison figures only. Many of the "close pairs" of lines are actually unresolved in

the solar spectrum, and it is evident that the wave-lengths of the components have only been determined approximately. Apart from these, there are many others which are difficult to measure on account of the lines being shaded or otherwise. Further, it has been found that many of Rowland's separations for close doubles are greatly overestimated. All the evidence obtained with high-power apparatus at Kodaikanal is decidedly against the probability of anomalous dispersion being an effective agent in displacing solar lines. C. P. B.

1332. *Masses of Visual Binary Stars.* **R. T. A. Innes.** (S. African J. Sci. 12. p. 453, 1916. Nature, 98. p. 99, Oct. 5, 1916. Abstract.)—From an investigation of binary stars, it appears that most close pairs are to be regarded as binaries, whether they show relative motion or otherwise. Assuming that a binary has the same brightness as the sun, the author calculates its distance from the apparent magnitude, and then the mass, if the period be known. The conclusion is that few double stars have a mass as large as the sun. The mass, or "gravitative power" as the author styles it, is found to be small in stars of types B and A, moderate in F, and large in G and K; in types O*e* and M it appears to be absent. It is suggested that light-pressure may partly or wholly neutralise gravitative power in stars of small density and great luminosity. C. P. B.

1333. *Distribution of B Stars.* **C. V. L. Charlier.** (Roy. Soc. Upsala, Nova. Acta, 4. Ser. 4. No. 7. Nature, 98. p. 116, Oct. 12, 1916. Abstract.)—From a detailed investigation of the proper motions and radial velocities of stars of type B it is concluded that they form a well-defined cluster, gradually thinning out from the centre to a distance of 200 siriometres (one siriometre = earth's distance from sun $\times$ 10^6). The centre of this cluster lies in a rich region of the constellation Carina, at the position RA = 7·7h.; Decl. = — 55·6°. A catalogue of 854 B stars is included, with data relating to details of type, magnitude, distance, galactic coordinates. C. P. B.

1334. *Spectroscopic Binary, χ Aurigæ.* **R. K. Young.** (Roy. Astron. Soc. Canada, J. 10. p. 358, 1916. Nature, 98. p. 116, Oct. 12, 1916. Abstract.) —An orbit for the spectroscopic binary χ Aurigæ has been computed from measurements on 88 spectrograms taken at the Ottawa Observatory during 1913–1916. The period of the star is $655·16 \pm 5·26$ days; eccentricity 0·171, and orbital velocity 20·53 km./sec. No evidence of the presence of a third body was detected. C. P. B.

1335. *Mean Distances of Stars.* **F. W. Dyson.** (Engineering, 102. p. 320, Oct. 6, 1916. Paper read before the British Assoc. at Newcastle.)—On the assumption that the peculiar movements of the stars neutralised one another when the mean of a large number was taken, the mean proper motion of a group in any part of the sky might be regarded as caused by the motion of the solar system towards a point near Vega (α Lyræ) with a velocity of 19·5 km./sec. This was then taken as a basis for determining the mean distances of stars of different magnitudes. The results obtained were in accordance (or gave slightly smaller parallaxes for faint stars) with Kapteyn's formula deduced by considering brighter stars. C. P. B.

1336. *Faint Stars with Large Proper Motions.* **R. J. Pocock.** (Roy. Astron. Soc., M.N. 76. pp. 657–659, June, 1916.)—A list is given of the numbers of faint stars with large proper motions determined from five recent Oxford plates measured at Hyderabad. C. P. B.

LIGHT.

1337. *Corrections for Concave Grating with Large Ruled Area.* **H. Nagaoka.** (Math. Phys. Soc., Tōkyō, Proc. 8. pp. 513–519, Sept., 1916.)—Now that gratings have been successfully ruled with much greater ruled area than in former times it becomes necessary to revise the theory by taking account of the higher order corrections which could be neglected for the smaller gratings. This is shown very clearly by comparing the results given by a large Michelson grating on the green mercury line with those given in work on the same line with interference apparatus, the echelon grating, Lummer-Gehrcke plate, or Fabry-Perot instrument. Formulæ are given showing the corrections to be used, with curves showing how they vary in importance with different angles of incidence. The only way to avoid these difficulties is to increase the radius of curvature or rule at closer intervals, or both. The matter needs careful consideration in all work involving positions of satellites or line structure, such as Zeeman-effect.

C. P. B.

1338. *Refractive Index and Dispersion of Glass.* **R. W. Cheshire.** (Phil. Mag. 32. pp. 409–420, Oct., 1916. From the National Physical Lab.)—This paper describes a new method of measuring the refractive index and dispersion of glass in lenticular or other forms, the procedure being based upon the "Schlierenmethode" of Töpler. The glass under examination is immersed in a liquid whose refractive index for the specified wave-length can be varied continuously until an equality is obtained between the index of the glass and that of the surrounding liquid. The ordinary process can then be applied to measure the refractive index of the liquid on the Pulfrich refractometer. A full description is given of the apparatus employed. The immersion fluid finally selected was an aqueous solution of mercury potassium iodide, more commonly known as Thoulet's solution. In its most concentrated form the refractive index for this solution for the D-line is 1·72, and this may be varied continuously down to 1·33 by admixture with increasing proportions of water. The results obtained show that the "Schlierenmethode" is well adapted for the equalising of the indices of the glass and liquid to one or two units in the fifth place of decimals, and is therefore all that is required in commercial practice. A. W.

1339. *Dispersion of Hydrogen and Helium on Bohr's Theory.* **C. Davisson.** (Phys. Rev. 8. pp. 20–27, July, 1916.)—Assuming the mechanism of dispersion to be that of the ordinary electronic theory of Drude and Lorentz, the author calculates the constants of the dispersion equation on Bohr's theory, for both elements, and compares them with the values obtained experimentally by C. and M. Cuthbertson [Abs. 362, 1727 (1910)] with the result that the divergence is so great that, if the mechanism of dispersion is rightly conceived, Bohr's theory is found quite incapable of accounting for the observed results. G. W. DE T.

1340. *Axial Velocity in Apparatus for Fizeau's Experiment.* **P. Zeeman.** (K. Akad. Amsterdam, Proc. 19. pp. 125–132, 1916.)—The author has now

made a direct optical measurement of the velocity of flow of the liquid at the axis in the apparatus he used for the repetition of Fizeau's experiment. It is found to be slightly different from what would be expected on the distribution according to the law of Poiseuille. But the result of the experiment is still largely in favour of the Lorentz expression. [See Abs. 682 and 1523 (1915).] E. H. B.

1341. *Infra-red Radiation of a Thin Metal Plate.* **C. W. Oseen.** (Ann. d. Physik, 50. 3. pp. 270–276, June 29, 1916.)—Mathematical treatment on the basis of the electron theory. [See Abs. 709 (1916).] E. H. B.

1342. *Theory of Colour.* **W. Ostwald.** (Phys. Zeits. 17. pp. 322–332, July 15, and pp. 352–364, Aug. 1, 1916.)—This is a discussion of the subject in general, and does not admit of brief abstract. Important points dealt with include colour mixture, the colour triangle, neutralisation and purity ratios, and colour brightness. A. W.

1343. *Modification of Violle Standard.* **H. E. Ives.** (Phys. Rev. 8. pp. 250–253, Sept., 1916.)—Considers the objections, theoretical and practical, to the Violle standard of light, and the suitability of Waidner and Burgess' suggested modification, viz. the intensity of the light emitted (white or monochromatic) by 1 cm.^{2} of a black body at the temperature of solidification of platinum [see Abs. 1786 (1908)]. Substituting for the light emitted by 1 cm.^{2} of the black body, the watt of luminous flux, the author enumerates the advantages of such a standard, among which is the fact that it colour matches the 4-watt carbon standards at present in use. J. W. T. W.

1344. *Bunsen-flame Spectra of Metallic Vapours.* **J. C. McLennan** and **A. Thomson.** (Roy. Soc., Proc. 92. pp. 584–590, Oct. 2, 1916.)—As the electrical conditions in flames are probably simpler than those which obtain in the electric arc or spark, it would be expected that, in flame spectra of the elements, the fundamental frequency would come out relatively with specially strong intensity. The results obtained with mercury and cadmium vapours go to confirm the view that the frequency $\nu = (1{\cdot}5, S) - 2, p_2)$ is a fundamental one. The fact that the cadmium line $\lambda = 2288{\cdot}79$ came out in strongly burning flames also gives support to the view that the frequency $\nu = (1{\cdot}5, S) - (2, P)$ possesses fundamental characteristics for Cd atoms. The experiments tend to support the view that, in the Mg spectrum, the fundamental frequency is given by $\nu = (1{\cdot}5, S) - (2, P)$. It is the one most easily stimulated in the spectrum of Mg. When the line $\lambda = 4571{\cdot}38$ has been observed by other spectroscopists, it has always been accompanied by other lines, including in some cases that of wave-length $\lambda = 2852{\cdot}22$. The results obtained with thallium failed to give any indication of the fundamental frequencies in the spectrum of this element. It is probable that in this case the fundamental spectral lines come far down in the ultra-violet region. [See also Abs. 1486 (1911) and 1408 (1915).] A. W.

1345. *Emission and Absorption in the Infra-red Spectrum of Mercury.* **R. C. Dearle.** (Roy. Soc., Proc. 92. pp. 608–620, Oct. 2, 1916.)—A continuation of previous work by McLennan and Dearle [Abs. 1663 (1915)]. The present paper deals with some additional work on the relative intensities of the lines in the infra-red region of the emission spectrum, and with the absorption bands produced by passing white light through non-luminous mercury vapour. It has been established that in the emission spectrum the

relative intensities of the lines in an individual series lie along a curve analogous to an energy curve, not only in the region of short waves but also in the long-wave region beyond the maximum of the energy curve. The intensities of the series lines become relatively greater in the shorter wave-lengths with increase in temperature. For the two lines $1{\cdot}014\,\mu$ and $0{\cdot}546\,\mu$, which do not belong to the same series, the intensity of the former becomes relatively greater for higher temperatures and vapour pressures, although it is the line of longer wave-length. In the absorption spectrum evidences of absorption have been found with each wave-length for which there is an emission line between $1{\cdot}00\,\mu$ and $1{\cdot}20\,\mu$. Strong absorption was obtained for wave-lengths $1{\cdot}014\,\mu$, $1{\cdot}129\,\mu$, and $1{\cdot}20\,\mu$. Absorption was obtained at wave-lengths $1{\cdot}014\,\mu$ and $1{\cdot}20\,\mu$ with very low vapour pressure. It has been shown that the two latter wave-lengths correspond to the first members of the series $\nu = (2{\cdot}5, \mathrm{S}) - (m, \mathrm{P})$, and $(1{\cdot}5, s) - (m, \mathrm{P})$ respectively.

A. W.

1346. *Ionisation Potentials of Magnesium and other Metals, and their Absorption Spectra.* **J. C. McLennan.** (Roy. Soc., Proc. 92. pp. 574–583, Oct. 2, 1916.)—In a previous paper [Abs. 565 (1916)] the author showed that when magnesium vapour in a vacuum is bombarded by electrons it is possible, if the electrons possess the requisite amount of kinetic energy, to cause the vapour to emit a radiation consisting of the single spectral line $\lambda = 2852{\cdot}22$. It has since been shown by Lorenser that this line is the first member of the series $\nu = (1{\cdot}5, \mathrm{S}) - (m, \mathrm{P})$ and that $\lambda = 2026{\cdot}46$ is the second member of the series. Hence, if Mg vapour acts as regards absorption in a manner analogous to the vapours of Hg, Zn, and Cd, bands should appear in its absorption spectrum at $\lambda\lambda = 4571{\cdot}38$, $2852{\cdot}22$, and possibly at $\lambda = 2026{\cdot}46$ and at still higher members of the series. The absorption spectrum of Mg was therefore re-examined, and the present paper gives an account of these experiments and of others which followed on from them. It was found that the absorption spectrum of non-luminous Mg vapour in a vacuum consists of narrow sharp bands at $\lambda = 2852{\cdot}22$ and $\lambda = 2026{\cdot}46$, *i.e.* at the points corresponding to the first two members of the series $\nu = (1{\cdot}5, \mathrm{S}) - (m, \mathrm{P})$. When Mg vapour in a vacuum is bombarded by electrons, no radiation characteristic of the spectrum of this metal is emitted until the electrons possess kinetic energy equal to that acquired in a fall of potential of about 4·5 volts. With a field corresponding to 5·9 volts the spectrum obtained consisted of a single line $\lambda = 2852{\cdot}22$, which was emitted strongly. No indication of the line $\lambda = 4571{\cdot}38$ was obtained under electronic bombardment until the electrons possessed sufficient kinetic energy to cause the arc to strike. The arcing voltage was approximately 7·5 volts. This, by the quantum theory, corresponds to the frequency of the line $\lambda = 1626{\cdot}66$, which is very close to $\lambda = 1621{\cdot}7$, the last line in the series given by $\nu = (1{\cdot}5, \mathrm{S}) - (m, \mathrm{P})$. With the vapours of Hg, Zn, Cd, and Mg, the arcing voltages appear to be connected by the quantum relation with the frequency $\nu = 1{\cdot}5, \mathrm{S}$. As the simplest Bunsen-flame spectrum of Mg vapour consists of the single line $\lambda = 2852{\cdot}22$, and as the vapour in the flame when emitting this radiation has been shown to be ionised, it would appear that the ionisation potential of Mg vapour also follows the quantum-theory law, and is given approximately by 4·28 volts. Arguments are presented which support the view that while the ionising potential for Hg, Zn, and Cd may be deduced from the quantum theory by the use of the frequency represented by $\nu = (1{\cdot}5, \mathrm{S}) - (2, p_2)$, in the case of Mg, Ca, Sr, and Ba the frequency which

must be used is given by $\nu = (1{\cdot}5, S) - (2, P)$. The absorption spectrum of non-luminous Tl vapour, with low densities, consists of a narrow sharp band at $\lambda = 3775{\cdot}87$, and with high vapour densities it consists of this band and somewhat diffuse ones at $\lambda = 3230$ and $\lambda = 3000$. Of these the line $\lambda = 3775{\cdot}87$ is the first member of the second subordinate doublet series given by $\nu = (2, p_2) - (m, s)$, and $\lambda = 3230$ is the second member of the second subordinate doublet series given by $\nu (2, p_1) - (m, s)$. No sign of absorption was observed at $\lambda = 5350{\cdot}65$, the first member of the latter series. The frequencies given by $\nu (1{\cdot}5, S) - (2, p_2)$ and $\nu = (1{\cdot}5, S) - (2, P)$ have not as yet been located in the spectrum of thallium. A. W.

1347. *Frequencies of Spectral Lines.* **W. M. Hicks.** (Engineering, 102. p. 321, Oct. 6, 1916. Paper read before the British Assoc. at Newcastle.)—A discussion of the question whether the frequencies of spectral lines can be represented as a function of their order. A. W.

1348. *Fluorescent Vapours and their Magneto-optic Properties.* **L. Silberstein.** (Phil. Mag. 32. pp. 265–282, Sept., 1916.)—A system obeying the differential equation $\ddot{x} + k\dot{x} + N^2x = 0$ is called here a *Hookean* resonator, and when such a resonator is acted upon by an external force of frequency n, it will only give oscillations of the same frequency, and will only respond vigorously when $n \doteqdot N$. If, however, N^2x is replaced by a non-linear function of x, an exciting force of frequency N will generate oscillations of frequency N and also an infinite variety of other frequencies. Bearing this in mind, the excitation and emission of fluorescent spectra may be mathematically described by saying (1) that the atoms of the vapour behave as if each contained a Hookean resonator under the simultaneous action of forces of all the frequencies $n_0 = N$, n_1, n_2, etc., *i.e.* by writing—

$$\ddot{x} + k\dot{x} + N^2x = c_0e^{iNt} + c_1e^{in_1t} + c_2e^{in_2t} + \ldots\ldots\ldots\ldots\ldots (1),$$

or (2) that each atom contains an appropriate non-Hookean resonator, acted upon by c_0e^{iNt} only, *i.e.* that—

$$\ddot{x} + k\dot{x} + N^2x + f(x) = c_0e^{iNt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2),$$

where $f(x)$ is some non-linear function of the displacement. It is here shown, following the method of successive approximations, that if the function $f(x) = ax^p$, where a is a real constant, and p is a real positive constant differing little from the value unity, a series is obtained whose members succeed one another at constant frequency-intervals $\delta n = (1 - p)N$. Recalculation of Wood's results for the three resonance series of iodine vapour excited by light of wave-length $\lambda = 5461{\cdot}0$, $5769{\cdot}5$, $5790{\cdot}5$ respectively shows a quite satisfactory constancy of δn along each series. Further development of the theory relative to the presence of a magnetic field shows that there should be no ordinary Zeeman-effect, which conclusion is not apparently contradicted by experiment, though Wood and Ribaud used fields up to 20,000 gauss. It also appears that the fundamental line of the series will continue to be rectilinearly polarised, but the plane of polarisation will be rotated round the magnetic field. For iodine vapour the angle is 45° for a field H_c of the order of 10^4 gauss. The other lines of the series become elliptically polarised. The theory is also in agreement with the results of Wood and Ribaud as regards the intensity of the fluorescence in a magnetic

field, for it is shown that with increasing magnetic fields the fluorescence tends to nothing. Wood and Ribaud found a 90 % reduction of the fluorescence in a field of 30,000 gauss. A. W.

1349. *Fluorescence and Absorption of certain Pleochroic Crystals of the Uranyl Salts.* **E. L. Nichols** and **H. L. Howes.** (Phys. Rev. 8. pp. 364–385, Oct., 1916.)—The study of the polarised spectrum of uranyl ammonium chloride [Abs. 1533 (1915)] has been extended to the potassium, rubidium, and caesium double chlorides. All these salts form triclinic crystals which are pleochroic and exhibit polarised fluorescence and absorption spectra. Unlike other uranyl compounds each type of spectra of these salts has its bands resolved at 20° C. into a homologous constant-frequency-interval series of five band groups. The fluorescence spectrum is essentially the same in structure for all four salts, and the spacing of the band members is the same in each group, except where overlapping takes place in the reversing regions between fluorescence and absorption. Each group band member is a doublet, the components being polarised at right angles to one another. The frequency-interval is practically the same for each series in any salt, and the average intervals of the four salts show a very slight decrease with increasing molecular weight in both spectra. There is also a slight systematic positional variation of a given band with molecular weight, the violet-ward shift from K to Cs being of the order of 5 Å.U. Moreover, this shift is experienced equally in extent and direction by each homologous series. Liquid-air temperatures produced the usual narrowing of the bands and apparent positional and interval changes, all of which are to be ascribed to the relative enhancement or diminution of components of the bands. C. S. G.

1350. *X-ray Spectra Produced by Means of Curved Crystal Surfaces.* **P. Cermak.** (Phys. Zeits. 17. pp. 405–409, Sept. 1, 1916.)—The first work of this kind was due to de Broglie [Abs. 878 (1914)], who used the curved surface of the crystal mica to determine the wave-lengths of lines in X-ray spectra. The method has been adopted frequently by other authors, various modifications being introduced, although the main principle remains the same. The author now describes an investigation in which other curved crystals have been studied in a similar manner. A crystal plate of rock-salt, heated to a temperature above 200° C., can be bent, and the bending results in a permanent deformation. Using such a crystal a line spectrum is obtained similar to that produced by the rotating crystal (plane-parallel) method. Similarly crystals of gypsum and diamond have been examined. Several interesting points with regard to the effect of bending crystals, etc., are raised. A. B. W.

1351. *Absorption Coefficients of Soft X-rays.* **C. D. Miller.** (Phys. Rev. 8. pp. 309–343, Oct., 1916.)—The object of the experiments described was to study the nature of X-rays produced at low potentials. For this purpose a specially constructed X-ray tube was employed, the very soft radiation being allowed to escape through a window (6 cm.^{2} in area) of Al leaf (0·000675 cm. thick). This Al leaf was supported by a phosphor-bronze gauze (180 meshes per inch), and under such conditions was found to be strong enough to bear the outside air pressure without serious leak. The tube was permanently connected to the exhaust pump, the pressure in the tube ranging from 10^{-4} and 10^{-5} mm. of Hg. The X-rays emerging through the window were detected and measured by means of an ordinary gold-leaf electroscope, the

bottom of which was covered with a sheet of Al leaf ($\frac{1}{10}$th the thickness of that covering the window of the tube).

The sheets of material used for absorbing the X-rays were of gelatin, celluloid, and aluminium. The results obtained are collected in the following table :—

Potential.	μ/ρ in Al.	μ/ρ in Celluloid.	μ/ρ in Gelatin.	$\frac{(\mu/\rho)\text{ Cell.}}{(\mu/\rho)\text{ Al.}}$	$\frac{(\mu/\rho)\text{ Gel.}}{(\mu/\rho)\text{ Al.}}$	$\frac{(\mu/\rho)\text{ Gel.}}{(\mu/\rho)\text{ Cell.}}$
2500	(1930)	—	312	—	—	—
3000	(1190)	—	193	—	—	—
3460	(778)	—	126	—	—	—
3930	(474)	81·0	76·2	—	—	0·940
4420	(351)	60·0	56·6	—	—	0·943
4880	(249)	42·5	38·7	—	—	0·910
5870	149	25·6	25·8	0·172	0·173	1·01
6780	101	—	—	—	—	—
7700	71·7	12·3	11·4	0·172	0·159	0·927
8860	47·3	—	—	—	—	—
9970	34·7	5·90	5·39	0·170	0·155	0·914
Mean				0·171	0·162	0·941

Plotting log V and log (μ/ρ) it is shown that the points for 4880 to 9970 volts, inclusive, lie remarkably close to a straight line.

The results give $\mu/\rho \,.\, V^{2\cdot 77} = 4{\cdot}24 \times 10^{12}$, which, combined with the quantum relationship $Ve = h\nu$, becomes $\mu/\rho = 19{\cdot}4\lambda^{2\cdot 77}$. Here λ is in Å.U., and μ/ρ is for Al. This result is in good agreement with that found by Siegbahn [Abs. 1052 (1915)], who obtained $\mu/\rho = 19\lambda^{2\cdot 78}$, using the absorption coefficients of the various characteristic radiations and the wave-lengths obtained by Moseley.

Curves showing how μ/ρ varies with the thickness of Al traversed are given. The author finds the relation $\rho d = 4{\cdot}4/(\mu/\rho)$ to hold good (ρd = mass per cm.^{2} of Al through which the rays have passed). A. B. W.

1352. *Symmetry of X-ray Patterns produced by Crystals.* **M. v. Laue.** (Ann. d. Physik, 50. 4. pp. 433–446, July 13, 1916.)—A mathematical paper in which a publication by Friedel [see Abs. 671 (1914)] is criticised. A. B. W.

RADIO-ACTIVITY.

1353. *The Straggling of a-Particles.* **W. Makower.** (Phil. Mag. 32. pp. 222–226, Aug., 1916.)—The results obtained by Geiger and by Taylor [Abs. 1248 (1910), 1966 (1913)] by the scintillation method for the variation in the number of α-particles from RaC in air are in substantial agreement, but the straggling indicated at the end of the range is considerably larger than is predicted by theory. In the present investigation, a photographic plate is substituted for the zinc sulphide screen, and the plate examined at leisure under the microscope. The results point to a more rapid falling-off in the number of α-particles at the end of their range than was previously indicated by the scintillation method. This tends to confirm the law given by Bohr's theory [Abs. 1720 (1915)]. E. A. O.

1354. *Reduction of the Velocity of α-Particles on Traversing Matter.* **L. Flamm** and **R. Schumann.** (Ann. d. Physik, 50. 6. pp. 655–699, Aug. 8, 1916.)—Measurements of this character were first made by Rutherford [Abs. 1712 (1906)] who suggested the relation $u = 0{\cdot}347\sqrt{(r + 1{\cdot}25)}$, where u represents the velocity (as a fraction of the initial velocity of α-particles from RaC) and r the *remainder* of the range of the α-particle. Later measurements by Geiger resulted in the expression $r = au^3$ (a = a constant). Still later Marsden and Taylor [Abs. 1837 (1913)] modified Geiger's formula to $r = au^K$, where K was a quantity constant for any given substance, but different for different substances. Thus $K = 3$ for air, but $K = 2$ for gold, and so on. They showed that for different materials also the factor a was almost exactly proportional to the square root of the atomic number of the substance.

The author proposes an expression containing three terms, of the type $x = \beta m + \gamma m^2 + \delta m^3$ [where $m = 2(1 - u)$], as more representative of the observed facts. Numerous tables of results are given, and from a consideration of these it is asserted that the above relation is more accurate than that proposed by Geiger, in spite of the generalisation contained in Geiger's formula. In addition to this the three-term equation admits of more accurate verification.

Graphical representation of the results shows that the falling-off in velocity between $u = 0{\cdot}60$ and $u = 0{\cdot}415$ is practically linear for all the substances examined. A. B. W.

1355. *Ionisation Tracks of Hydrogen Particles, produced by the Collision of α-Particles with Hydrogen Atoms.* **D. Bose.** (Phys. Zeits. 17. pp. 388–390, Aug. 15, 1916.)—By means of a photographic arrangement on the lines of the Wilson expansion apparatus, the author has obtained very good photographs showing the ionisation tracks of H-particles, which have been produced in the passage of α-particles through hydrogen. The paths of the deflected α-particles, on intimate collision with the atom of hydrogen, are also visible on the same photographs, the effect appearing like a fork at the end of the straight ionisation track made by the α-particle in traversing the gas.

The number of α-particles deflected through any angle is found from the photographic records to be in good agreement with the number calculated according to the theory of Rutherford and Darwin [Abs. 1347 (1911) and 1032 (1914)]. A. B. W.

1356. *Application of Quantum Hypothesis to Theory of the Photoelectric Effect and of the β-radiation from Radio-active Substances.* **P. S. Epstein.** (Ann. d Physik, 50. 7. pp. 815–840, Aug. 17, 1916.)—The paper begins with a short history of the work of Bohr in connection with the application of the quantum theory to the atom, the spectra of hydrogen and helium, etc. [see Abs. 1930 (1913), 1070 (1914)]. Sommerfeld's work is considered in a similar manner. A mathematical discussion follows, results deduced from the theoretical conclusions being compared with the experimental observations of Rutherford and Robinson, v. Baeyer, Hahn, and Meitner in connection with the standard determination of velocities of β-rays. The calculated and observed results are in excellent agreement, giving strong support to the author's views. A. B. W.

HEAT.

1357. *Condensation of Metallic Vapours on Cooled Bodies.* **M. Knudsen.** (Ann. d. Physik, 50. 4. pp. 472–488, July 13, 1916.)—When mercury vapour condenses on a glass surface which is cooled to the temperature of liquid oxygen, a transparent layer first becomes noticeable which is quite feebly reflective and shows a brownish tint by transmitted white light. As the condensation continues the layer gradually becomes more opaque and reflective. The formation of the layer gives rise to the belief that every mercury molecule which strikes the strongly cooled surface remains adhering, while the probability of being repelled is very small. In order to determine whether this probability is of observable dimensions, the author has made some experiments from which the calculation is made that every mercury molecule which strikes a body cooled to the temperature of liquid oxygen adheres at the first impact. On the other hand, when a mercury molecule strikes a glass surface cooled to $-77 \cdot 5°$ C. the probability of adherence at the first impact is 1/5000. A mercury surface cooled to $-63°$ C. retains almost all the impacting mercury molecules, and would retain the whole if the mercury surface were perfectly pure. A series of experiments at temperatures lying between the temperatures of liquid oxygen and solid carbonic acid demonstrated that a cooling to about $-140°$ C. causes glass to retain every molecule impacting upon it, and, should this temperature be raised to about $-130°$, then repulsion again takes place when the mercury molecule attains a velocity corresponding to the ordinary room temperature. A critical point thus appears to lie between $-140°$ and $-130°$ C. The corresponding points have also been determined for sal-ammoniac (below $-183°$ C.), zinc, cadmium, and magnesium (all between $-183°$ and $-78°$ C.), copper (between $-350°$ and $575°$ C.), and silver (above $575°$ C.). It has also been shown that the single molecules or small molecular aggregates which adhere to glass may be expelled by other impacting molecules. This is apparently closely connected with the phenomenon of supersaturation, and doubtless points to a state of instability consequent on slowly developing processes.

An exhaustive account of the experimental details is given, illustrated by numerous diagrams and photographs. H. H. Ho.

1358. *Condensation and Reflection of Gas Molecules.* **R. W. Wood.** (Phil. Mag. 32. pp. 364–371, Oct., 1916.)—The author previously showed that a jet of mercury vapour in which the molecular motion was restricted to one dimension is reflected from a flat plate of glass approximately according to the cosine law [Abs. 1397 (1915)]. It is now found that for various substances there is a sort of critical temperature, surprisingly low, below which condensation appears to occur at the first collision; in other words, the chance of reflection is zero. For mercury this critical temperature is near $-140°$, for cadmium about $-90°$, and for iodine about $-60°$. Many details as to working and behaviour are given in the paper, also four photographs of the apparatus and effects. E. H. B.

1359. *Internal Friction (Viscosity) in Gases. I. The Primary Viscosity Coefficient.* **M. B. Weinstein.** (Ann. d. Physik, 50. 6. pp. 601–654,

Aug. 8, 1916.)—In his book on Thermodynamics the author has derived an equation for the viscosity coefficients of gases based upon previous work on entropy, which is distinguished from all other formulæ in that it takes account indirectly of the relationship of the specific heats and number of atoms, in addition to the usual quantities of density, pressure, temperature, and molecular weight. In Boltzmann's book the equation has been somewhat generalised. In the present paper the author gives a further investigation which attains the limitations imposed by the fundamental assumptions. As a consequence of establishing the theory as completely as possible in accord with present experience, the greater part of the paper consists of numerical calculations in support of earlier deductions. The theory itself still depends on the use of classical opinions, as, in spite of the work of Einstein, Debye, Sommerfeld, and others, the author has not succeeded in being able to employ Planck's quanta theory. In like manner he has had to relinquish improving the formulæ for the rotation of molecules.

The author first deals with his general expression for the viscosity coefficient, and introduces the specific heats at constant volume and temperature, afterwards determining the relationship between the absolute temperature and the forces due to molecular and atomic motions. For this latter purpose four standpoints are considered : (1) The internal and external potential and kinetic energies. (2) The internal energy alone. (3) The equation of state. (4) The molar forces regarded as independent of the nature of the gas. The case of a perfect monatomic gas is first taken, and all four viewpoints are shown to give the same results. The dependence upon temperature receives detailed consideration, since all previous experiments have shown that the viscosity coefficient increases at a greater ratio than the square root of the temperature. Any theory in support of a lower power than the square root is unknown to the author. Various gases are reviewed both from the author's standpoint and those of other investigators, and numerous tables of data are given. It follows that for the dependence of the frictional coefficients of vapours and gases on the temperature a simple formula with only two constants cannot be universally established ; the present theory, however, permits of deriving a series of such formula from which the suitable one for the particular case in hand can be extracted. In most cases the following simple formulæ are the most advantageous, namely, $\eta = a\sqrt{\theta}(1 + b\theta^{-1/3})$ or $\eta = a\sqrt{\theta}(1 + b\theta^{5/6})$, where η is the viscosity coefficient, θ the absolute temperature, and a and b are constants. The viscosity coefficients are next considered at constant temperature, with varying pressures and volumes. Numerous cases are taken, and results given in great detail. Finally the author investigates the dependence of the viscosity upon molecular weight and atomic number. Such dependence has already been proposed, but in the absence of a sufficiently rigorous theoretical basis. H. H. Ho.

1360. *Internal Friction (Viscosity) in Gases. II. The Second Viscosity Coefficient, the Gustav-Kirchhoff Thermodynamic-hydrodynamic Equations, and the Maxwell Gas Theory.* **M. B. Weinstein.** (Ann. d. Physik, 50. 7. pp. 796–814, Aug. 17, 1916.)—On the usual theory the second viscosity coefficient is estimated at one-third of the primary in order to make the average of the normal pressure equal to the static pressure, and to establish for the normal pressure the same formulæ as for the chief pressure, so that independence of the choice of coordinate systems may be achieved. The author proves on thermodynamic grounds that every relation $\eta' = \frac{1}{3}\eta$ is neither thermodynamically admissible nor even an approximate equation, and he derives

an expression, $\eta_1 = \frac{1}{3}\eta + \frac{1}{6}\eta[1 + \frac{3}{2}(k-1)/(2\lambda/\eta - 1)]$, where η and η_1 are the primary and secondary viscosity coefficients, k the ratio of the specific heats at constant pressure and constant volume, and λ the temperature-conductivity. This expression has been derived from a special case, but has been established independent of special conditions. It is shown that the Maxwell gas theory admits of a second viscosity coefficient which depends on k and λ/η. The Poiseuille problem also comes under review as a special case of Maxwell's theory, and affords an interpretation of the pressure components. The Gustav-Kirchhoff theory of the thermodynamic-hydrodynamic gaseous equations contains as many relationships as quantities to be determined, namely, six. By special application to motions under the conditions assumed, difficulties arise in that more equations are to hand than quantities to be determined, and here the thermodynamic relationships play an important part, since they deviate in their form completely from the equations of motion. H. H. Ho.

1361. *The Method of Logarithmic Isochromes.* **C. Schaefer.** (Ann. d. Physik, 50. 7. pp. 841–852, Aug. 17, 1916.)—The method was given in a paper by E. Benedict [Abs. 1699 (1915)] and consists in comparing photometrically the intensities of particular wave-lengths of a "black" body whose temperature is varied with those of the same wave-lengths in the spectrum of a "grey" body at a constant temperature T_0. It is found that there is a linear relation between log E_λ and $1/T$, and that these straight lines, or Logarithmic Isochromes (Log. Isos.) meet in a common point, this point corresponding to the required temperature T_0. Further mathematical treatment is given, and it is shown that the graphical method followed by Benedict can be greatly improved upon by taking the Log. Isos. two and two and employing the method of least squares. The method gives very good results for a carbon filament, but not for a metal one. In the latter case the relation between log E_λ and $1/T$ is linear, but the lines do not intersect at the same point owing to the presence of a correction involving λ. The effect of the correction is to displace each line a certain distance in a direction parallel to itself. When this is done a common intersection point can again be obtained, and T_0 determined.

The converse problem—also discussed by E. P. Hyde [Abs. 698 (1916)]—is also attacked mathematically, and it is shown that even if the Log. Isos. meet in a common point the source is not necessarily grey, and the cutting point does not necessarily give the temperature of the radiator. T. B.

1362. *Physical Structure of the Phase Medium.* **M. Planck.** (Ann. d. Physik, 50. 4. pp. 385–418, July 13, 1916.)—Since the meeting of the first Solvay Congress in Brussels, Poincaré, who then opposed the newly proposed quanta-hypothesis according to which a system with several degrees of freedom must be divided into quanta, has placed the most severe obstacles against its development. The author now believes himself to have given, in the present communication, an answer carrying a certain amount of general significance. In order to achieve his object a certain physical structure has to be attributed to the phase medium, which, without being contradictory, is nevertheless quite alien to classical dynamics. The paper, subdivided into 16 sections, is a mathematical exposition defining the phase medium. Prior to this publication, Sommerfeld, from the standpoint of the spectral lines problem, has found the same remarkable results, so that the author claims hereby to have a direct ratification of his theory. H. H. Ho.

SOUND.

1363. *Acoustic Demonstration and Pulse Theory of Radiation.* **P. W. Cobb.** (Science, 44. pp. 283–284, Aug. 25, 1916.)—The following quickly set-up arrangement occurred to the author as demonstrating an analogy to what is understood to occur on the pulse theory of radiation.

A glass bottle contains a variable quantity of water to tune it as a resonator to a certain note. Its mouth is fitted with a funnel whose wide upper end is covered with paper tied on. On this diaphragm silver sand pours in a stream from a suitable glass jet. Thus a series of irregular impulses are given to the paper and diaphragm, and the point of interest was to observe if this evolved the proper sound to which the bottle was tuned, whatever its exact pitch. It was found that this sound was feebly elicited. E. H. B.

1364. *Period of Spherical Resonator with Circular Aperture.* **F. P. White.** (Roy. Soc., Proc. 92. pp. 549–555, Sept. 1, 1916.)—In a paper on the theory of the Helmholtz resonator, Rayleigh carried the determination of the wave-length of the fundamental aerial vibration in a spherical vessel with a small circular perforation to a second approximation [Abs. 357 (1916)]. The present author by a slightly different assumption, carries the result to a higher approximation. He thus obtains for the wave-length $\lambda = \pi(2S/a)^{1/2}(1 - 0{\cdot}14324a/c - 0{\cdot}019617a^2/c^2 + \ldots)$, where S is the volume of the sphere, c its radius, a the small radius of the aperture. E. H. B.

1365. *Vibrations and Deflections of Membranes, Bars, and Plates.* **Rayleigh.** (Phil. Mag. 32. pp. 353–364, Oct., 1916.)—In his "Theory of Sound" the author has shown that any contraction of the fixed boundary of a vibrating membrane must raise the pitch, because the new state of things may be conceived to differ from the old merely by the introduction of an additional constraint. Based on this principle a number of relations are here adduced as to membranes, bars, and plates. The paper is largely mathematical. E. H. B.

1366. *Wolf Note in Bowed Stringed Instruments.* **C. V. Raman.** (Phil. Mag. 32. pp. 391–395, Oct., 1916.)—A fuller account of the work previously dealt with [Abs. 1052 (1916)]. E. H. B.

1367. *Sound Pressure.* **F. Küstner.** (Ann. d. Physik, 50. 8. pp. 941–954, Sept. 5, 1916.)—Full mathematical treatment yielding some results in accord with Rayleigh's. [See Abs. 1297 (1914).] E. H. B.

1368. *Anomalies in Sound Propagation.* **F. Nölke.** (Phys. Zeits. 17. pp. 283–287, July 1, 1916.)—A paper supplementary to a previous one dealing with the zone of silence and second audible region in the case of explosions and other intense sources of sound [see Abs. 708 (1916)]. Cases are treated in which the temperature gradient is small and large, and diagrams given illustrating each case. E. H. B.

1369. *Resonance and Interference Phenomena in Seebeck's Tubes.* **K. L. Schaefer.** (Ann. d. Physik, 50. 6. pp. 700–712, Aug. 8, 1916.)—An experimental paper dealing with the exact positions of the maxima and minima with the tube devised by Seebeck in 1870, and giving directions for the best results. E. H. B.

ELECTRICITY AND MAGNETISM.

THEORY, ELECTROSTATICS, AND ATMOSPHERIC ELECTRICITY.

1370. *Electrodynamics and the Least Action Principle.* **G. H. Livens.** (Phil. Mag. 32. pp. 195–200, Aug., 1916.)—Solutions have been given by Larmor, Lorentz, Macdonald, and others, of the problem of the complete formulation of the laws of electrodynamics by their derivation in the form of a variational theorem. The integral subject to variation is in all cases virtually the same, namely: $\int_{t_1}^{t_2}\left[L + \int\left\{\frac{1}{2c}(AC - \frac{1}{8\pi}E^2\right\}dv\right]dt$, where L is the part of the Lagrangian function of the system independent of the field conditions; A is the vector potential of the magnetic field; C is Maxwell's total current; and E is the electric force intensity at the typical field point. From analogy with the known properties of electrostatic fields, E^2 may be assumed to represent the true potential energy of elastic strain in the ether, both as to total amount and distribution, in which case the kinetic energy of electric origin in the ethereal field will be represented by $\frac{1}{2c}\int(AC)dv$. But for most applications of electromagnetic theory it is more convenient to assume the magnetic energy, regarded for other reasons as kinetic, to be distributed with the density $B^2/8\pi$, where B is the vector of magnetic induction. The two expressions for the magnetic energy do not, however, in the most general case, agree, for as Macdonald has pointed out ["Electric Waves," App. C] in deriving one from the other by integration by parts, an integral over the infinite boundary is brought in which is not generally negligible, which raises a question as to the legitimacy of the procedure. Larmor has attempted its justification [Lond. Math. Soc., Proc. (1915)] by the examination of a special restricted problem, and, on the relativity tivity theory, the demonstration can be obtained generally by means of the Minkowski differential invariant theory.

The author has succeeded in obtaining a general formulation of the general dynamical theory on the basis of the more usual expression of the kinetic energy in terms of B. Starting with the Lagrangian function, $L + \int\frac{1}{8\pi}(B^2 - E^2)dv$, he overcomes the difficulty arising from this form of function not being explicitly expressed in terms of the independent coordinates by the use of Lagrange's undetermined multipliers, which makes an explicit interpretation of the functions unnecessary. The four scalar relations between E and B and the coordinates of the electrons require four such multipliers, all functions of position in the field. They turn out to be the scalar potential, and the three components of the vector potential, of Maxwell's theory. The equations obtained by equating to zero the coefficients of the three virtual electronic displacements and of the two expressing condition variations in the ether are found to be $E + 1/c\,.\,\partial A/\partial t + \text{grad}\,\phi = 0$, $B - \text{curl}\,A = 0$, and, for each electron, three equations of the type,

$$\frac{d}{dt}\cdot\left(\frac{\partial L}{x}\right) - \frac{\partial L}{\partial x} - \frac{e}{c}[v\ \text{curl}\ A]_x + \frac{e}{c}\frac{\partial A_x}{\partial t} + e\frac{\partial\phi}{\partial x} = 0,$$

where ϕ is the scalar, and A the vector, potential. The second simply identifies three of the multipliers—to a numerical factor—with the components

of the vector potential, while the others are identical with those of Larmor, and show that the dynamical equations determining the strain conditions of the ether and the motions of the electrons, are identical on either form of the theory. And this covers the whole field of physical activity, except, possibly, radiation. For purely radiation portions of the field, having their energy equally divided between the potential and kinetic types, this is unrepresented in the generalised Lagrangian function of the system. Thus, from the point of view of the dynamics of the electron, the purely radiation portions may be omitted, and this procedure will secure the analytically necessary localisation of the fields, which is essential to the mathematical developments of either form of the theory, and it removes the origin of the discrepancy between the two elements of the magnetic energy in the field. It would thus justify a further simplification of the problem by restricting it to stationary or quasi-stationary motions, and fully confirms the generality of Larmor's procedure.
G. W. DE T.

1371. *Existence of Sub-electrons?* **R. A. Millikan.** (Ann. d. Physik, 50. 7. pp. 729–768, Aug. 17, 1916.)—An historical and critical survey of the idea of an elementary quantity of electricity with special reference to the question as to the possible existence of a sub-electron. The author's chief conclusions may be summarised as follows:—(1) Ehrenhaft has only made approximate tests as to whether the Einstein-Brownian motions for his particle gave the same value of Ne as electrolysis. The author's work proved it for mercury particles of radius $2{\cdot}5 \times 10^{-5}$. Fletcher and Eyring found a good agreement with oil spherules of about the same size. It appears probable that the equation is valid for Ehrenhaft's particle also if it were exactly tested. (2) This rejection of the equation has no relation to the question as to the existence of sub-electrons. It signifies simply that the Einstein equation in gases is not applicable to all particles of that magnitude. (3) All Ehrenhaft's results may be explained easily by the supposition that he made false assumptions as to the density and spherical form of his particles. Even if these assumptions were correct his case would not be proved. It would simply show that he had a false law of fall in a gas for his extremely small charged particles. (4) Up to the present, in the author's view, no proof has been given for the existence of sub-electrons.
E. H. B.

1372. *Influence of Earth's Motion on Self-induction.* **A. v. Schütz.** (Phys. Zeits. 17. p. 391, Aug. 15, 1916.)—A general discussion on the possibility of such an influence.
E. H. B.

1373. *Some Problems of Atmospheric Electricity.* **G. C. Simpson.** (Monthly Weather Rev. 44. pp. 115–122, March, 1916.)—The paper commences with a discussion of the general principles which govern the distribution of electricity on the surface of the earth and in the atmosphere. The author then considers various problems which in the present state of our knowledge remain unsolved. (1) The presence of free ions in the atmosphere is generally considered to be due to the action of radio-active matter. The amount of the radio-active matter present in the earth and the atmosphere is here compared with the number of ions per cm.^{3} in the air, and it is found that over land the existence of the ions can be satisfactorily accounted for in this way. On the other hand, the number of ions over the sea is about three times that which we should expect to find on this theory. It is concluded that the radio-active theory of the ionisation of air over oceans

is not satisfactory. Problem (2) is connected with the earth's penetrating radiation. If air is placed in a closed box and freed from all radio-active matter it is found that ionisation still goes on, and this can only be ascribed to γ-radiation which penetrates the walls of the box. It is found that the γ-radiation from the earth is capable of producing 3 ions per $cm.^3$ per sec., and that there is a further radiation coming from above which produces 2 per $cm.^3$ per sec. near the ground-level. This is too large to be accounted for by the radio-active emanation in the atmosphere. Further, balloon observations show that the rate of production of ions in the closed box begins above a certain height from the ground to increase rapidly, and at 6000 m. height 30 more ions per $cm.^3$ per sec. are produced than at the surface of the earth. This can only be due to some radiation coming from the sky. At present no satisfactory explanation is forthcoming of this penetrating sky radiation. (3) The third problem dealt with is the well-known one of the origin and maintenance of the earth's negative charge. Most of the existing theories on this subject are considered unsatisfactory by the author, who here goes into the problem in some detail. He makes a suggestion that possibly a solution may be found on the following lines. It has been demonstrated that the ratio of the mass to the electrical charge of a moving body varies with its velocity, and More has suggested that it is not the mass that varies but the electrical charge. The present author points out that, using this hypothesis, if the velocity of the earth relative to the centre of gravity of the universe is changing, the charge which appears on the surface and which is continually passing away through the atmosphere may be the consequence of this change of velocity. (4) The fourth problem concerns the nature of ball lightning. Strutt has shown that by means of an electric discharge a mass of nitrogen can be put into a state in which it continues to glow for some time after it has been removed from the electric field. The author suggests that the body of the ball lightning may be some gas made to glow in this way by the intense discharge of a lightning-flash. The paper concludes with a discussion of the nature and origin of the aurora. J. S. Di.

1374. *Pyro- and Piezo-electricity of Crystals.* **W. Voigt.** (Phys. Zeits. 17. pp. 287–293, July 1, and pp. 307–313, July 15, 1916.)—The first of these papers deals with the properties of the central symmetrical excitations, the second with the influence of the absolute value of the dielectric moment on the observable phenomena. Both are largely mathematical. [See Abs. 1749 (1915).] E. H. B.

DISCHARGE AND OSCILLATIONS.

1375. *The Square-root Law of Alkali Flames and the Theory of Flame Conduction.* **E. Marx.** (Ann. d. Physik, 50. 5. pp. 521–554, July 25, 1916.)—The author has previously determined a special law for the observed drift velocity of negative carriers of electricity in flames from measurements of the Hall-effect. The velocity v of the negative carriers is inversely proportional to the square root of the atomic weight of the alkali metal in the flame, that is, $v\sqrt{(A)} = \text{const.}$ Later Moreau, independently and by quite different methods, obtained confirmatory evidence of the truth of this law. In the present paper an equation for the observed drift velocity is given which shows that, in accord with previously obtained results of Marx and Moreau, the observed negative drift velocity is inversely proportional to the square root of the atomic weight of the metal atoms in the flame, and, further, that the observed drift velocity is inversely proportional to the square root of the concentration.

The observed drift velocity of the free positive metal atom, which drifts without a nucleus, is independent of the atomic weight. These light-metal atoms carry in the mean manifold charges. The Arrhenius relationship between the current and atomic weight of the metal atoms in the flame, obtained also independently, and in quite a different form, by Smithells, Wilson, and Dawson, can be understood by taking the field distribution into consideration, and shows that the emission of electrons from the alkali atom is proportional to the atomic weight. The drift velocity in the flame is inversely proportional to the square of the pressure, not to the pressure itself. The experiments of Andrade are in accord with the result.

The theory of conduction in flames is developed on the basis of the above hypothesis by taking the field distribution into consideration.

A. E. G.

1376. *Photoelectric Effect on Thin Films of Platinum.* **J. Robinson.** (Phil. Mag. 32. pp. 421–425, Oct., 1916.)—The photoelectric current from thin films of Pt does not increase uniformly with the film thickness, but increases gradually at first, then suddenly increases rapidly, after which it falls again. This applies whether the incident or emergent effect is considered, *i.e.* whether the light falls on the film before or after passing the supporting quartz plate. For thicknesses below about 10^{-7} cm. (where the current is a maximum) the emergent effect is larger than the incident both as regards currents and velocities. Partzsch and Hallwachs showed that more light is absorbed by the film in the emergent case than in the incident. This shows the necessity for further work to find (1) what is the asymmetry of the currents, emergent and incident, when unit quantity of light is absorbed in each case, and (2) whether for very thin films the absorption of light varies with the thickness in a way similar to that of the current. The present work attempts to obtain information on these points.

In order to find the light absorbed by the film, it is placed in a nearly closed metallic cylinder and a beam of ultra-violet radiation projected through a small inlet on to the film. Very little light which enters the vessel can escape again. Light which is not absorbed by the film is absorbed by the walls of the vessel: the amount absorbed by the film is given by subtracting from the total light that absorbed by the vessel. This last is proportional to the photo-currents from its walls, and the total light to the current from the wall when the film thickness is zero. Hence by measuring the currents from the walls for different film thicknesses a curve can be constructed connecting the light absorbed by the film (in arbitrary units) and the film thickness. This increases uniformly with the thickness. The curve for current from film and thickness of film is of the usual type. It is evident then that the large photo-current at thickness 10^{-7} cm. is not produced by abnormal absorption of light. A curve is also given of the photo-current per unit of light absorbed, and the max. value of the current is still more pronounced. The photoelectric sensitiveness of Pt is thus very large for films of the order of 10^{-7} cm. T. H.

1377. *Ionisation of Metallic Vapours in Flames.* **J. C. McLennan** and **D. A. Keys.** (Roy. Soc., Proc. 92. pp. 591–608, Oct. 2, 1916.)—The experiments here described show that mercury vapour which is fed into the flame of a Bunsen burner is ionised, and the radiation from the vapour consists of light of wave-length $\lambda = 2536{\cdot}72$. Zinc vapour, when injected into Bunsen flames, is not ionised, and does not emit any light characteristic of the

spectrum of zinc. A Bunsen flame which is supplied with cadmium vapour emits light of wave-length $\lambda = 3260 \cdot 17$ when the intensity of the flame is weak, and when burning strongly it emits light of wave-length $\lambda = 2288 \cdot 79$ as well. The cadmium vapour in such flames does not appear to be ionised. Magnesium vapour which is fed into the flame of a Bunsen burner emits light of wave-length $\lambda = 2852 \cdot 22$, and the vapour in the flame is ionised. Thallium vapour, when fed into a Bunsen flame, becomes strongly ionised, and under these circumstances emits light of wave-lengths $\lambda = 5350 \cdot 65$ and $\lambda = 3775 \cdot 87$. The combined results of the investigation neither conclusively support nor definitely tend to invalidate Bohr's theory of atomic structure. [See Abs. 1408 (1915).] A. W.

1378. *Residual Ionisation.* **K. H. Kingdon.** (Phil. Mag. 32. pp. 396–409, Oct., 1916.)—In these experiments it is shown:—(1) That the high residual ionisation in acetylene prepared from calcium carbide is due to the presence of slight traces of radium emanation. (2) That only a portion of the ultimate residual ionisation in gases can be due to the collisions of thermal agitation. (3) A formula for the number of collisions per cm.^{3} per sec. producing ionisation has been devised which is in qualitative agreement with experimental facts. [See Abs. 1448 (1915).] E. H. B.

1379. *Velocity of Secondary Kathode Rays emitted by a Gas under the Action of High-speed Kathode Rays.* **M. Ishino.** (Phil. Mag. 32. pp. 202–222, Aug., 1916.)—The author has investigated the distribution of the velocities of the secondary kathode rays emitted from air and hydrogen under the action of kathode rays having velocities ranging from 7000 to 15,000 volts. It is found that the corpuscles are emitted with velocities varying from 0 up to 1000 volts, but that about 90 % of them have velocities less than 40 volts. The distribution of the velocities of the secondary kathode rays is almost independent of the velocity of the primary kathode rays, and it is approximately the same for air and for hydrogen. The distribution curve may be represented by the empirical formula $y = Cx^{-a}$ over a range from $x = 40$ volts to $x = 700$ volts, where y indicates the relative number of the secondary kathode rays emitted with velocities greater than x volts, and a is a constant differing but slightly from unity. The value of this constant is therefore in accordance with the theory of ionisation given by J. J. Thomson [Abs. 1084 (1912)]. Some points of similarity between the secondary kathode rays from a gas and from a metal are mentioned. E. A. O.

1380. *Experiments with Electron Currents in Different Gases.* I. *Mercury Vapour.* **O. W. Richardson** and **C. B. Bazzoni.** (Phil. Mag. 32. pp. 426–440, Oct., 1916.)—Measurements were made of electron currents flowing in mercury vapour under measured p.d.'s from an incandescent tnngsten filament to a cold anode of nickel wire. The photoelectric effect of the radiation from the discharge was also examined. Curves showing the relation between current and p.d. are given. For low filament temperatures the current, for low voltages, increases at a rate greater than the first power of the voltage, but at higher potentials assumes a saturation value. For higher filament temperatures the type of curve is similar for p.d.'s up to about 20 volts, but here a discontinuity occurs, a "kick-up" of the current appearing when the voltage is raised. Thus, in one case, when the driving potential rose to 22 volts the current suddenly jumped from 130 microamps. to 1100 microamps. At the same time the resistance to the discharge fell so

that only 21 volts was required to maintain the larger current. On lowering the voltage the large current was maintained below 21 volts, but when 17 volts was reached the current suddenly dropped to the lower curve again and the p.d. rose to 19 volts owing to the increased resistance of the gap. The magnitude of this kick of the current depends on the pressure of mercury vapour as well as on the temperature of the filament. At low and high vapour pressures the kick is small, and is a maximum for some intermediate pressure. Increasing the filament temperature or the mercury vapour pressure also lowers towards a limiting value the potential at which the kick occurs. The lowest value of the p.d. necessary to maintain the discharge in a state corresponding to the upper part of the curve is 11·5 volts, and it therefore appears necessary that the electrons should be able to acquire energy equivalent to a fall through a p.d. close to this value for the discharge to be maintained in this state. This is nearly the sum of the kathode and anode potential-drops in the ordinary luminous mercury arc. With small potential differences, v, the currents are roughly proportional to $v^{3/2}$. Langmuir has accounted for this when the gas pressure is very low, but his assumption that the electrons move freely between the electrodes without interference or collisions with gas molecules is not satisfied with pressures of the order of 1 mm. The authors show that with monatomic gases for low p.d.'s a similar result is to be expected even at high pressures.

With pressures of the order of 0·001 mm. of mercury there is no evidence of any visible discharge, but when the current jumps to the higher curve a large photoelectric emission sets in. With certain filament temperatures a very small emission can be detected before the jump up, but it is difficult to be sure that the small effects are not due to hydrogen or some other contaminant present in quantities not spectroscopically detectable. When hydrogen is present (as before occluded gases are completely eliminated) it is found that a considerable emission of ultra-violet radiation sets in at the small potential differences.

At pressures greater than 0·01 mm. the jump up of the current is always accompanied by the establishment of a visible glow discharge and a vigorous ultra-violet emission, but no emission could be detected at potentials less than that at which the glow sets in. The behaviour of this glow with changes in potential across the discharge is studied in some detail. Spectroscopic examination of the glow was also made to see if there is any difference in the potentials necessary to excite different lines of the mercury spectrum, especially the strong lines 4358 and 5460. No such effect was found. The potentials required to excite the lines mentioned are identical to within 1/10 volt. By the quantum theory the equivalent voltage difference of the two lines is 8/10 volt. This indicates that the lines of the mercury arc spectrum are not separately excited by single electron impacts, one for each line, but are the result of a complex change set up in the atom affecting a large number of electrons simultaneously. T. H.

1381. *Mean Free Path of an Electron in a Gas and its Minimum Ionising Potential.* **K. T. Compton.** (Phys. Rev. 8. pp. 386–390, Oct., 1916.)—There is a certain gas pressure for which the current through an ionised gas reaches a max. value. This value of the pressure may be calculated by each of the various theories of ionisation by collision and compared with the observed values. Such a test of the theories has an important advantage over the usual comparison of predicted and observed values of α, in that it is independent of the distance between the electrodes in the gas and is therefore

not subject to the error in calculating α introduced by the fact that all the electrons leaving the kathode travel a certain distance through the gas before any of them acquire the minimum ionising velocity.

The author uses equations recently proposed by him and deduces the relation $p_m NV_0/x = 0{\cdot}655$, where p_m is the gas pressure at which the current through the gas is a maximum, N the number of collisions made by the ion per cm. in a gas at 1 mm. pressure, V_0 the minimum ionising potential, and x the electric intensity. NV_0 is Stoletow's constant. Partzsch's experimental values of p_m for different gases in various electric fields are used to test this relation by calculating NV_0. There is a remarkable constancy of the product deduced from different measurements on the same gas. It is also in agreement with the values of NV_0 found in previous papers.

Some experimental determinations of N, which are still being made, indicate that it is not a simple function of the mean free path of a gas molecule nor of the molecular dimensions as calculated by the kinetic theory. It also depends on the work done on the electron as it approaches a molecule and on the nearness of its approach, and therefore on the law of force between electrons and molecules. T. H.

1382. *Luminosity of Positive Column in Gases at Low Pressures.* **H. A. Wilson.** (Phys. Rev. 8. pp. 278–284, Sept., 1916.)—In the positive column the current is carried by negative electrons and positive ions, present in nearly equal numbers. As the velocity of the former is so much the greater the current is practically all carried by the electrons. If i be the current and e the charge on each electron, i/e gives the number of electrons passing per sec. through any cross-section of the positive column. Assume that the emission of any particular spectral line is due to collisions between the electrons and the molecules, but that these collisions do not cause any emission unless the velocity of the electrons be greater than a certain value. Also assume that the amount of light emitted is proportional to the number of collisions which produce emission. Let λ be the mean free path of the electrons; $i/e\lambda$ will be the number of free paths per sec. in one cm. of the positive column. Let x be the shortest free path, which can give rise to emission; then the number of free paths, per sec. per cm. of the positive column, which can give rise to emission is $i\epsilon^{-x/\lambda}/e\lambda$, and the emission should be proportional to $i\epsilon^{-x/\lambda}/e\lambda$. Assume that the energy of an electron at the end of a free path x is proportional to xX, where X is the potential gradient; this would be the case if the electrons lost all their energy at each collision. Let $x\mathrm{X}=\mathrm{V}$, a constant; and let $\lambda^{-1} = \mathrm{C}p \times 273 \times \theta^{-1}$, where C is the number of mean free paths per cm. at 1 mm. Hg pressure and 0° C., p the gas pressure, and θ the absolute temperature. Then $(i\epsilon^{-x/\lambda})/e\lambda = (273\mathrm{C}pi/e\theta)\epsilon^{-\mathrm{VC}\,.\,273/\mathrm{X}\theta}$; and if I be the amount of light of wave-length λ emitted by the positive column per sec., we have $\mathrm{I} = \mathrm{A}\,(273pi/\theta)\epsilon^{-273\mathrm{VC}p/\mathrm{X}\theta}$. Then let t = the temperature in deg. C., $= \theta - 273$, and write $(273+t)/273 = f$; we have $\mathrm{I} = \mathrm{A}(pi/f)\,.\,\epsilon^{-\mathrm{VC}p/\mathrm{X}f}$. From this, $\log_\epsilon(\mathrm{I}f/ip) = \log_\epsilon \mathrm{A} - (\mathrm{CV}p/\mathrm{X}f)$. Therefore $\log_\epsilon(\mathrm{I}f/ip)$ should be a linear function of $(p/\mathrm{X}f)$ and the slope of the line should be CV. Hence, if we know I, p, i, X and t we should be able to determine CV: and if C be known we can calculate V. Experiments to test this were made on helium, nitrogen, hydrogen, and mercury in hydrogen, with confirmatory results. The values of CV obtained were He, $\lambda = 5876$, CV = 10; N, 6015, 96; H, 6562, 130; Hg in H, 5461, 130. It appears that an electron can cause a molecule of nitrogen to emit light when the electron's energy is less than the average energy required to ionise the molecule. The

small value of CV found in helium is no doubt due to the electrons not losing all their energy on collisions, but accumulating it until it becomes sufficient to produce ionisation, and the apparent free path is therefore very long, so that C is very small. A. D.

1383. *Discharge in a Magnetic Field.* **A. Righi.** (Accad. Sci. Bologna, Mem. [Ser. VII] 3. [22 pp.] 1915–16.)—In previous experiments (Accad. Sci. Bologna, Rend., May 29, 1910 ; Mem. March 26, 1911) the author had found that a magnetic field profoundly modified the sparking-potential and the sparking distance of a discharge in rarefied air. He obtained characteristic curves for strength of field and the potential necessary to initiate a discharge. In general as the strength of field rises the required p.d. falls to a minimum, then rises to a maximum, and again falls off. The tubes used in the first series of experiments had long parallel electrodes ; the form ultimately used in the second series had coaxial cylinders. The effect of residual ionisation perturbed the results of successive experiments on the same tube. Since the characteristic curve has the form indicated, a given p.d. (ordinate) may cut it or not according to the strength of the magnetic field ; and a given p.d. may thus correspond to two or more strengths of field as representing the minimum p.d. capable of initiating a discharge. Therefore we may have, as the strength of the field rises, that a given p.d. is first found inadequate to cause a discharge ; then a discharge abruptly commences and is maintained throughout a certain range of strength of field, but abruptly breaks off when the field has attained a certain higher value. It is not sufficient to consider the deviations undergone by the ions and electrons ; another action comes into play, and this is the author's magneto-ionisation, the resultant effect of a feeble magnetisation of the gas ; the resultant force is directed outwards along the radius of the trajectory. This weakens the force which holds the electron in its orbit, and thus favours ionisation by impact. The electric field also has an analogous effect. The mutual inclination of the two fields might be expected to modify the results, according to whether the impinging electron, driven by the electric field, caught the gas-atom in the plane or at right angles to the plane of rotation of its electrons or any of them. Experiments were made to test these and similar conclusions. They were made with tubes having parallel electrodes far from one another. With electrodes 120 cm. apart with a p.d. of 5200 volts between them, a magnetic field being applied longitudinally at the centre of the tube through a length of 5 cm., it was found that the discharge began when the field came up to 4900 gauss, the air in the tube being under a pressure of 0·26 mm.; but if the magnetic field be transverse to the tube (at its centre) the effect is opposite and the field hinders the discharge. The results are opposite to what would have been anticipated had the deviation of moving particles by the field been the only factor to consider ; the effect of this is overpowered by the magneto-ionisation effect, until the strength of the magnetic field attains a certain value. Slight changes in the pressure of the gas give rise to considerable changes in the form of the characteristic curve. As the p.d. necessary to initiate a discharge falls to a minimum when the strength of the magnetic field rises, so at the same time the current produced by a given impressed p.d. rises to a maximum ; whence measuring the current offers a ready means of tracing out the trend of the characteristic curve. A. D.

1384. *Theory of Glow Discharge.* VI. **R. Holm.** (Phys. Zeits. 17. pp. 402–405, Sept. 1, 1916.)—The sixth of a series of papers. The present one is largely mathematical and derives formulæ and points out agreement with the observations of J. Stark (1901) and of N. Hehl (1902). E. H. B.

1385. *Electric Wave Transmission on the Earth's Surface.* **H. M. Macdonald.** (Roy. Soc., Proc. 92. pp. 493–500, Aug. 1, 1916.)—Love has found the value of the magnetic force at a point on the earth's surface, due to a simple oscillator placed on the surface with the axis normal thereto, at certain distances from the source, for a wave-length of 5 km. [Abs. 1109 (1915)]. For the case of perfect conductivity his results agree with those obtained by the author [Abs. 1313 (1914)], and he has also calculated the sum of the corresponding series for the case of imperfect conductivity. The author here obtains a general formula in which imperfect conductivity is taken into account. At distances from the source for which the first terms of the series gives a sufficient approximation to the value of the magnetic force, the effect of imperfect conductivity is to multiply the amplitude of the magnetic force for perfect conductivity by a factor which increases with the angular distance from the oscillation and diminishes as the wave-length increases. The effect of the second-order terms is to decrease this factor. When these are neglected the values of the factor for a wave-length of 5 km. agree with the results obtained by Love for angular distances of 6°, 9°, 12°, 18° from the oscillator, but there is a discrepancy in the values corresponding to 15°. For distances not exceeding 4000 km. the effect of imperfect conduction is to increase the amplitude of the magnetic forces by an amount not exceeding 6·5 %. If it can be assumed that the value 10^{14} for the specific conductivity of sea-water, as used in the calculation, is of the right order in the case of very long waves, then it will follow that the effect of the imperfect conductivity of the sea-water on the transmission of such waves over its surface is practically negligible. G. W. DE T.

1386. *Theory of Electric Oscillations.* **P. Duhem.** (Comptes Rendus, 162. pp. 815–820, May 29, 1916.)—The author here develops some general theories from which the important conclusion is deduced that a true electric oscillation cannot be excited in any system containing conductors, so that there is, strictly speaking, no such thing as electric resonance in such a system. The observed phenomena can be represented approximately only by a theory of resonance. G. W. DE T.

1387. *Law of Response of the Silicon Detector.* **L. S. McDowell** and **F. G. Wick.** (Phys. Rev. 8. pp. 133–141, Aug., 1916.)—The authors have made a study of the silicon detector designed by Merritt in order to determine (i) the best working conditions, and (ii) the law of response with a variation in the energy of the incident wave, produced by the rotation of a screen of parallel wires. The oscillator consisted of a small spark-gap in kerosene, extended by two straight Al wires and connected through water resistances to the secondary of a small induction coil. The water resistances served to damp any oscillations from the coil which might have produced disturbances. The spark fluctuations were so small that observations made at intervals of 30 minutes agreed almost exactly. The receiver consisted of a silicon detector in series with a 1-mfd. condenser and a wire loop which could be set in various planes. A sensitive galvanometer was shunted across the condenser terminals, and an Al rod acting as a resonator was supported parallel and near to the outer wire of the wire loop. The wave-length was 100 cm. Between the receiver and the oscillator was a large screen of wire-netting which completely divided the room into two parts. This screen was pierced by a circular hole 125 cm. in diam. which was covered by a rotatable screen consisting of parallel wires 3 cm. apart. Experiments were made with the

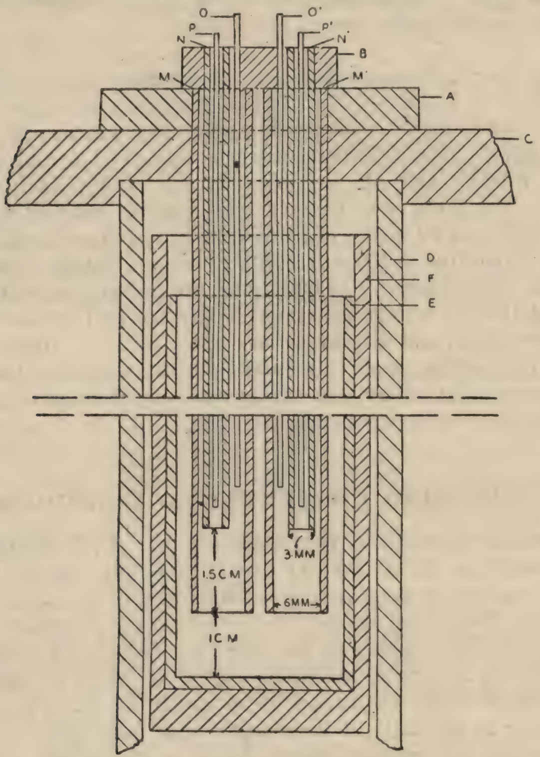
receiver in vertical and horizontal planes and with the intervening wires making angles with the vertical of 0° to 360°. It is shown that certain irregularities which had been observed by Merritt are to be attributed to diffraction. Austin had previously shown that for alternating currents of ordinary frequencies and for oscillations of a frequency of 140,000 the rectified currents are approximately proportional to the square of the alternating currents. The results obtained by the authors confirm this law for a frequency of about 3×10^8. I. W.

ELECTRICAL PROPERTIES AND INSTRUMENTS.

1388. *Electrical Resistivity of Bismuth.* **A. Werner.** (Phys. Zeits. 17. pp. 346–349, Aug. 1, 1916. From the Physikal.-Techn. Reichsanstalt.)—The investigations of Cohen and Moesveld have shown that bismuth exists in two allotropic forms, α-Bi and β-Bi, the transition-point at atmospheric pressure being 75° C. At the Reichsanstalt 11 samples of Bi of known varying degrees of purity have been prepared by different methods, and their resistivities determined by the ordinary compensated fall of potential method at a temperature of 22° C. The commercially pure samples contained Ag, Pb, Cu, Zn, and Ni, while the electrolytically purified samples contained Pt and Ag. Those samples were specially purified to a very high degree. The samples were drawn into wire in a heated hydraulic press from which air was excluded. Wires about 1 mm. diam. and 17 cm. long were drawn at three accurately measured temperatures, 155°, 195°, and 230° C. The results obtained confirm Lenard's earlier observations, and show that the temperature at which the wire was drawn affects the results. Differences of 1 % or 2 % were observed for the very pure specimens, while in the case of some of the others the differences varied from 6 % to 12 %. For all the samples the smallest value of the resistivity was observed for wires drawn at 195° C. The three specially purified samples had resistivities 1·19, 1·20, and 1·20 when drawn at 195° C. One of them had resistivities of 1·21, 1·19, and 1·20 corresponding to the three temperatures of drawing, 155°, 195°, and 230° C.; the second had the values —, 1·20, —; and the third the values 1·22, 1·20, 1·20. One of the impure samples had the three values 3·30, 3·09, and 3·32. The temperature coefficient of resistivity for the very pure samples over the range 18° to 25° was + 0·0040. The author's samples were purified chemically, and he considers that it is easier to purify Bi in this way than by the electrolytic method. I. W.

1389. *Resistivity of Molten Metals.* **E. F. Northrup** and **R. G. Sherwood.** (Frank. Inst., J. 182. pp. 477–509, Oct., 1916.)—Describes a piece of apparatus, termed a resistometer, for the determination of the resistivity of molten metals. The first type (shown in the Fig.) consists of an alundum crucible, E, into the top of which fit two blocks of Alberene stone, A, B, each holding a pair of quartz or porcelain tubes, MM′, NN′. Within these tubes are tungsten wires of about 1 mm. diam., one pair of which, OO′, act as current leads, while the other pair, PP′, act as potential leads. The crucible E is placed in a container, F, made of Acheson graphite (to obtain a reducing atmosphere in the furnace) and is filled with the metal to be tested to a depth sufficient to reach a little above the lower ends of the current leads. The heater unit consists of an alundum tube, D, wound with nichrome wire or ribbon. A second type of instrument, more convenient for some kinds of work, is also described. One advantage of this second type is its compact-

ness and the fact that if filled with some metal (*e.g.* tin) it can be used as a pyrometer (in this case up to 1600° or 1700° C., since the resistance of tin increases linearly from its melting-point up to at least 1680° C.). The large e.m.f.'s of a parasitic character which are developed in the resistometer when this is immersed in a molten metal preclude the use of direct current for measuring purposes. Alternating current of 60 and 25 cycles is therefore used, and the specially sensitive type of a.c. galvanometer employed is described in the paper. The resistometer is calibrated in mercury of accurately



measured temperatures. When used as a pyrometer it is necessary to take a cooling-resistance curve. The point at which the resistance remains constant for a considerable period is the known freezing temperature of the pyrometric metal (*e.g.* tin) and the resistance at this point is the resistance of the pyrometer at that known temperature.

The paper concludes with an account of some experiments with the resistometer on the resistivity of Pb, Bi, Sn, Bi + Pb alloys, and several Bi + Sn alloys. All these metals and alloys showed a linear resistivity-temperature relation in the molten state. J. W. T. W

1390. *Resistance of Various Sodium Amalgams.* **R. C. Rodgers.** (Phys. Rev. 8. pp. 259–277, Sept., 1916.)—The change of resistance of several sodium amalgams was ascertained with change of temperature from − 185° to 150° C., and the depression of the freezing-point of mercury in amalgams of small atomic percentage was studied by the method of the sudden change of resistance of the amalgam due to the change to the solid state. A. D.

1391. *Resistance and Reactance of Massed Rectangular Conductors.* **A. Press.** (Phys. Rev. 8. pp. 417–422, Oct., 1916.)—The solution of the skin-effect of rectangular conductors given by H. W. Edwards [see Abs. 1562 (1911)] is applicable only to small conductors. The solution given in this paper applies to both small and large conductors. The only important assumption made is that the current in the skin of the conductor has a rectangular path conforming to the contour of the conductor. Considering the complexity of the problem, the mathematical solution obtained is comparatively simple. The author proves that J. J. Thomson's results for an infinite plate is a particular case of his solution. A. R.

1392. *A New High-tension Battery.* **H. Greinacher.** (Phys. Zeits. 17. pp. 343–346, Aug. 1, 1916.)—The author describes a continuation of his work on the rectification of alternating currents by means of Graetz valves [Abs. 594 (1915)]. The individual valves consisted of cylinders about 5 cm. high, fitted with Fe and Al electrodes and containing $NaHCO_3$ solution as electrolyte. The latter was covered with paraffin oil and the battery of valves was insulated by means of paraffin wax. In the original form the a.c. supply was drawn from a 100-volt lighting circuit; now it is taken from the secondary of a transformer. At 6000 volts the current was 0·005 amp. The constancy of the d.c. voltage generated is affected by the pressure variations of the supply circuit and also by an admixture of 1 per 1000 of alternating potential. The battery requires a little time to attain the steady state, and the voltage cannot be subdivided. It is, however, cheaper to construct and maintain than the ordinary accumulator form. I. W.

ALTERNATING CURRENTS AND INSTRUMENTS.

1393. *Wehnelt Kathode-ray Tube Magnetometer.* **C. T. Knipp** and **L. A. Welo.** (Phil. Mag. 32. pp. 381–391 Oct., 1916.)—The authors have recently described a method for determining the horizontal component of the earth's magnetic field depending on the measurement of the magnetic and electrostatic deflections of a beam of kathode rays [Abs. 1571 (1915)]. In the present paper, by measuring the deflection of the beam (1) under the action of "H" alone, (2) under the action of H combined with a known magnetic field, the value of the ratio of the charge to the mass of the electron, which was necessary in the previous investigation, is eliminated. The discharge tube was a vertical cylinder with the kathode at the bottom. The kathode was adjustable so that the beam travelled up the axis of the tube and impinged on a photographic plate at the top. The applied magnetic field was obtained by passing a known current round a vertical coil of about 40 cm. radius wound with six turns of wire. The vertical diam. of this coil was coincident with the axis of the discharge tube. It was found sufficiently accurate to take the distribution of the field perpendicular to this diam., as that obtaining along the path of the beam. To set the plane of the coil perpendicular to the magnetic meridian a test plate was taken with the coil in a chosen position. The angle through which the coil must be rotated to bring its plane perpendicular to the meridian was then measured on the photographic plate. The results of seven determinations are given in the paper, the mean value of H being 0·1583 c.g.s. unit. The relative probable error of the deviations of the several determinations from the mean is $\pm$ 0·00046. L. L.

CHEMICAL PHYSICS AND ELECTRO-CHEMISTRY.

1394. *Hardening and Tempering of Eutectoid Steel.* **H. M. Howe** and **A. G. Levy.** (Mech. Eng. 38. pp. 231–232, Sept 22, 1916. Abstract of paper read before the Am. Soc. for Testing Materials.)—The results of the study of the Shore hardnesses and changes of volume occurring in a eutectoid steel after quenching from a descending series of temperatures show that as the temperature of quenching approaches A*r*1, a gradual decrease occurs in the volume with very little change in the hardness. As the quenching temperature is lowered from immediately above to immediately below A*r*1, a sudden decrease in volume occurs, and is accompanied by a sudden loss of hardness. Further lowering of the temperature does not affect the volume, showing that the change completes itself when the temperature passes A*r*1. The hardness, however, continues to decrease, on account of the coalescence of the cementite and the ferrite.

F. C. A. H. L.

1395. *Effect of Sulphur on Low-Carbon Steel.* **C. R. Hayward.** (Am. Inst Mining Eng., Bull. No. 118. pp. 1841–1850, Oct., 1916.)—Gives the results of mechanical tests on steels containing 0·04, 0·085, and 0·15 % sulphur, the other elements except Mn being approximately the same in each steel. In the case of Mn, the amount in excess of that necessary to form MnS was approximately the same. The bars were tested after heating to 880° C. and quenching in ice water ; cooling in still air ; cooling in the furnace ; and also after quenching from 880° and reheating to 300°, 400°, 500°, and 600° C., thus giving results after seven different thermal treatments.

The results of the tensile tests indicate that sulphur does not lower the tensile strength and the results for elongation and reduction of area show that there is little difference in ductility between the low- and medium-sulphur steels but the ductility of the high-sulphur steel is slightly lower than the other two after most of the treatments.

The average figures for shock tests, carried out on a Charpy machine, except for the air-cooled and furnace-cooled specimens, are highest for each treatment in the case of the low-sulphur steels and lowest for each treatment for the high-sulphur steels. The widest difference appears in the steels which have been quenched and reheated. C. O. B.

1396. *Thermoelectric Measurement of the Critical Points of Iron.* **G. K. Burgess** and **H. Scott.** (Comptes Rendus, 163. pp. 30–32, July 10, 1916. Also Engineering, 102. pp. 391–392, Oct. 20, 1916. Paper read before the Iron and Steel Inst.)—A 0·5-mm. wire of pure iron was welded at its two ends to the junctions of two le Chatelier thermo-couples and heated in an electric resistance furnace. Measurements of the temperatures at both ends of the iron wire were made and the Pt-wires were attached to a sensitive galvanometer which gave an indication of the e.m.f.'s of the Fe-Pt couple for the differences of temperature between the two ends of the iron wire. The results are finally plotted in the form of curves showing the true thermoelectric power of the Fe-Pt couple for small differences of temperature as a

function of the temperature. A3 is shown as a sharply defined discontinuity, while A2 is shown as an inflection in the curve at 768° C. It is also evident that the two transformations are of a different character, since A2 occurs at the same temperature both on heating and cooling, while A3 occurs at a lower temperature on cooling than on heating. F. C. A. H. L.

1397. *Electrical Phenomena at the Surface of Separation between Aqueous Solutions and Insulators.* **G. Borelius.** (Ann. d. Physik, 50. 4. pp. 447–472, July 13, 1916.)—The first part of the paper deals with the phenomena and the research methods employed. These phenomena, electrical and otherwise, which take place at the separating surfaces of aqueous solutions and different substances are in general traced to one or more of three causes, namely : (1) The substance may pass as molecules or ions into the solution ; (2) the substance may itself be a solvent so that the dissolved electrolytes or its ions distribute themselves between the water and the substance ; (3) the dissolved electrolytes or its ions may be adsorbed at the surface of separation. The author has investigated such cases where aqueous solutions are in contact with good insulating solids or liquids which are unattacked as far as possible, and where the third possibility is chiefly to be expected as a consequence. The question is investigated as to how far the surface phenomena may be traced to adsorption alone. To acquire knowledge of the structure of the surface layer, a study has been made of the different phenomena which take place there, and their dependence on the nature and concentration of the electrolyte. The methods which have been employed are :—Direct measurement of the surface potential by means of bad conductors. Measurements of electro-kinetic or electro-osmotic effects. Estimation of electrification by contact action. Precipitation of suspended particles by electrolytes. Measurement of the surface tensions at the separation layer. Absorption measurements. The author hopes to establish the Helmholtz theory that all these effects are to be traced to the change of potential between the adhering layers of the moving solution and the boundary surface. In the last few years a series of researches on solutions in contact with insulators have been carried out by different methods, and these are especially comprehensive with respect to glass, quartz, and paraffin. Since glass and quartz are not typical insulators for the special purpose in hand, the author has made his investigations with paraffin, this being specially suitable in view of the series of homologous paraffins with different melting-points, so that measurements can be taken both with solid and liquid substances. The author describes at some length his direct potential measurements at the boundary surface between paraffin and a large number of aqueous solutions. Numerous tables are given. He next deals with regularities in the boundary potentials between univalent electrolytes and paraffin, afterwards studying the influence of the valency of the kathions by a comparison of the direct and cataphoresis measurements of the boundary potential. The electrical contact phenomena due to the electrification of insulators by contact with different electrolytes are next dealt with. Following this comes a discussion of the nature of the boundary potential and the dimensions of the separation layer. The interpretation of the empirical regularities at higher concentrations then receives attention. The author concludes that the boundary potential, such as occurs at the higher concentrations, is to be regarded as a diffusion potential. H. H. Ho.

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Bulletins of the Hill Observatory, Salcombe Regis.

Proceedings of the National Academy of Sciences, U.S.A.

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